Influence of harmonics in magnetic shielding of extremely low frequency power cables

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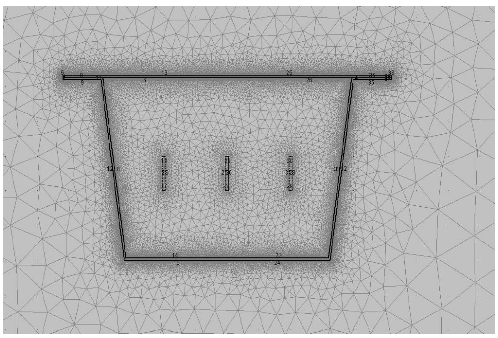
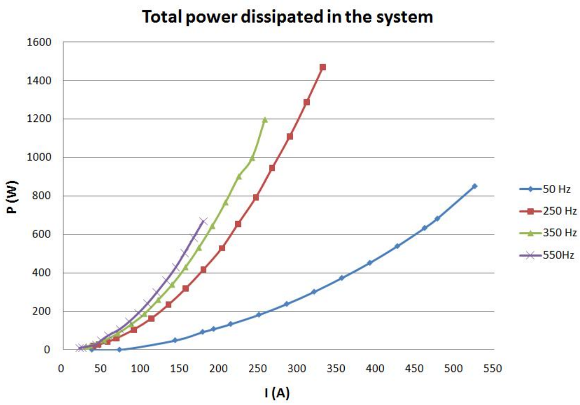
In literature, many papers deal with shielding of extremely low frequency power cables, e.g. with complex shaped non-ferromagnetic materials [1] or very thin high permeability sheets [2]. In our study, we consider shielding by U-shaped gutters with cover plates (see Fig. 1a), made in a 3 mm thick hot rolled ferromagnetic steel with $\leq$0.18% C and $\leq$0.50% Si. We focuss on the power losses in the magnetic shield, in particular in the case that harmonics are observed in the waveforms in the cables.

In the 3 mm thick steel plates of the shield, the induced currents contribute strongly to the over-all field reduction of about 20 dB. It is therefore not surprising that the classical losses are the dominant loss term for both the 50 Hz fundamental wave and for higher harmonics. A 2D finite element model (FEM) was made in order to compute the classical loss in the time domain. The hysteresis losses and the excess losses are found from a time domain loss model. Both the loss model and the *BH* characteristic in FEM are based on hysteresis loop measurements in an Epstein frame. The FEM and loss model are useful to compute the shield losses for any waveform of the phase currents.

To validate the FEM, the losses are measured in a laboratory setup that consists of a three phase power source with harmonic waveform synthesis, connected via a three phase transformer to 8 m long shielded phase conductors. The power in the shield is determined by subtraction of corresponding loss measurements with and without shield. Fig. 1b shows the measured power losses of the complete three phase system for several harmonics. The full paper will show measured and simulated losses in case of waveforms that contain several harmonics.



(a)



(b)

Figure 1: (a) FEM geometry; (b) Measured loss in the three phase system for sinusoidal currents at several frequencies

[1] E. Cardelli, A. Faba, and A. Pirani, IEEE Trans. Magn. **46** (2010), 889-898.

[2] S.B. Kim et al., IEEE Trans. Magn. **46** (2010), 682-685.